Lasers in Surgery and Medicine 18:167–170 (1996)

Effects of Diode Laser Welding With Dye-Enhanced Glue on Tensile Strength of Sutures Commonly Used in Urology

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Background and Objective: **Tissue welding using laser-activated protein solders may soon become an alternative to sutured tissue approximation. In most cases, approximating sutures are used both to align tissue edges and provide added tensile strength. Collateral thermal injury, however, may cause disruption of tissue alignment and weaken the tensile strength of sutures. The objective of this study was to evaluate the effect of laser welding on the tensile strength of suture materials used in urologic surgery.**

Study Design/Material and Methods: **Eleven types of sutures were exposed to diode laser energy (power density = 15.9 W/cm^2) for 10, 30, and 60 seconds. Each suture was compared with and without the addition of dye-enhanced albumin-based solder. After exposure, each suture material was strained (2″/min) until untimate breakage on a tensometer and compared to untreated sutures using ANOVA.**

Results: **The strength of undyed sutures were not significantly affected; however, violet and green-dyed sutures were in general weakened by laser exposure in the presence of dye-enhanced glue. Laser activation of the smallest caliber, dyed sutures (7-0) in the presence of glue caused the most significant loss of tensile strength of all sutures tested.**

Conclusion: **These results indicate that the thermal effects of laser welding using our technique decrease the tensile strength of dyed sutures. A thermally resistant suture material (undyed or clear) may prevent disruption of wounds closed by laser welding techniques.**

Key words: anhealing, genitourinary, soldering

INTRODUCTION

Laser-activated protein solders have been used either in conjunction with sutures or in an attempt to minimize or replace them. The latter method has been used particularly where foreign body is prone to the development of urolithiasis, stricture, or fistula formation and has been used by our group to perform urethral reconstruction [1,2] and ureteral reimplantation [3] with great success. In the case of tissue repairs with sutures sealed with solder, the solder is placed over the sutures and exposed to laser energy. Collateral thermal energy in this scenario may significantly decrease the tensile strength of underlying sutures and thus may cause failure of tissue approximation. An assessment of the effects of laser energy on suture material is warranted.

Accepted for publication August 20, 1994.

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MATERIALS AND METHODS

Suture materials common to the practice of urologic surgery were tested. These included: 4-0 chromic cat gut (Ethicon, Sommerville, NJ); polyglactin 910 coated with polyglactin 370 and calcium stearate (4-0, 5-0, 6-0, violet-dyed and undyed, braided Vicryl [Ethicon]); 5-0 plain gut (Davis-Geck, Danbury, CT); polydioxanone (5-0, 7-0, violet monofilament, PDS*II [Ethicon]); and polyglyconate (7-0, green monofilament, Maxon [Davis-Geck]).

Sutures were tied into loops ~2.5 cm in diameter. Each set of sutures were divided into three groups as described by Ashton et al. [6]. Group 1 (untreated control) received neither glue application nor laser activation. Group 2 was exposed to 60 seconds of laser energy alone. Group 3 received both dye-enhanced albumin-based glue application (1 drop, albumin 160 mg/ml, sodium hyaluronate 4.2 mg/ml, and indocyanine green 0.42 mg/ml) and laser activation (10, 30, 60 seconds). Laser activation was performed with an 808 nm diode laser (Diomedics, The Woodlands, TX) using a power density of 15.9 W/cm^2 (power = 0.5 W, spot diameter = 2 mm, pulse duration = 0.5 seconds, interpulse interval = 0.1 seconds, fluence = 8.0 J/cm^2 per pulse). Since the knot represents the weakest point in the suture loop, laser activation was directed over the knot in all cases. Our favorable clinical [4] and experimental [1–3] experience using this laser and glue combination enhanced the practicality of the current study.

Each of the three suture groups were strained at a rate of 2″/min using a Table Model 1130 Instron tensometer (Instron, Canton, MA) until ultimate breakage. Comparisons were made between the breaking force at each time interval among the various groups using ANOVA. Data are expressed as an average ± SD.

RESULTS

The tensile strength data for the 11 suture types are listed in Table I. The breaking point of the suture loop was at the level of the knot in almost every suture tested. A summary of these data is listed below according to group.

Group 1. As expected, greater tensile strength was found among the larger caliber sutures, with the 4-0 sutures stronger than the 7-0 sutures. Within the same caliber suture, cat gut was weaker than the braided or monofilament sutures.

Group 2. Laser exposure for 60 seconds, in the absence of glue, had no significant effect on any of the sutures tested.

Group 3. With the exception of 5-0 polyglactin (violet-dyed), a decrease in tensile strength was observed in dyed sutures exposed for >30 seconds in the presence of glue. Of the 4-0 sutures tested, dyed polyglactin was the least tolerant of laser energy, retaining 53% of its original strength by 1 minute. No significant decrease in tensile strength was demonstrated in the undyed 4-0 sutures (polyglactin and chromic gut).

Of the 5-0 sutures tested, the tensile strength of polydioxanone (violet) was most significantly affected by laser activation, retaining only 43.7% of its initial strength by 30 seconds. The remaining 5-0 sutures tested were not significantly affected by laser activation and in the cases of undyed polyglactin and plain gut, appeared to increase in strength upon laser activation.

The presence of dye in the 6-0 polyglactin group appeared to weaken its baseline tensile strength (33.7% loss) compared to undyed suture material of the same caliber (17.9% gain). These data, however, did not reach statistical significance.

Laser activation of the 7-0 caliber suture material in the presence of glue caused the most significant loss of tensile strength of all sutures tested. By 1 minute exposure time, polydioxanone (violet) and polyglyconate (green) lost 50% and 45.5% of their tensile strength, respectively. Significance was achieved at both the 30-second and 60-second exposure times in polydioxanone material, whereas significance was not achieved until 60 seconds in polyglyconate sutures.

DISCUSSION

Laser welding for primary anastomoses has been used by our group experimentally to perform bladder closure in extravesical ureteral reimplantation [3], and both skin tube [1] and bladder mucosa patch graft [2] urethroplasty. Clinically, our method has been used in reinforcing urethral and ureteral anastomoses (Kirsch, unpub. data), and vascular [5], biliary, pancreatic, and intestinal anastomoses at risk to leakage and subsequent morbidity [4]. Sutures are essential in aligning tissues in the case of *sutureless* tissue welding, and in providing additional tensile strength in *laser-assisted* tissue welding. In both cases, it is critical to know what the effects of laser activa-

TABLE I. Laser-Suture Material Interaction

Suture material[a]		N[b]	Strength (KgF)[c]	Retention
4-0 Chromic gut				
Group 1		6	2.11 ± 0.10	100.0%
Group 2		5	1.98 ± 0.10	93.8%
Group 3:	10 s	4	2.17 ± 0.10	102.8%
	30 s	4	1.99 ± 0.13	94.3%
	60 s	4	1.97 ± 0.13	93.4%
4-0 Polyglactin (undyed)				
Group 1		5	3.06 ± 0.13	100.0%
Group 2		5	3.10 ± 0.09	101.3%
Group 3:	10 s	6	3.06 ± 0.12	100.0%
	30 s	6	3.11 ± 0.08	101.6%
	60 s	5	2.93 ± 0.20	95.8%
4-0 Polyglactin (violet-dyed)				
Group 1		14	3.23 ± 0.19	100.0%
Group 2		4	3.25 ± 0.27	101.3%
Group 3:	10 s	4	3.36 ± 0.20	104.0%
	30 s	4	2.91 ± 0.60	90.1%
	60 s	5	1.72 ± 0.97**	53.3%**
5-0 Polyglactin (undyed)				
Group 1		6	1.81 ± 0.04	100.0%
Group 2		5	1.93 ± 0.04	106.7%
Group 3:	10 s	5	1.67 ± 0.04	92.3%
	30 s	5	1.33 ± 0.25	73.4%
	60 s	5	1.25 ± 0.37	69.1%
5-0 Polyglactin (violet-dyed)				
Group 1		6	1.75 ± 0.07	100.0%
Group 2		5	1.80 ± 0.08	102.9%
Group 3:	10 s	5	1.92 ± 0.07	109.7%
	30 s	6	2.12 ± 0.07	121.1%
	60 s	5	1.68 ± 0.14	96.0%
5-0 Plain gut				
Group 1		6	1.43 ± 0.06	100.0%
Group 2		6	1.61 ± 0.08	112.6%
Group 3:	10 s	6	1.76 ± 0.07	123.1%
	30 s	6	1.71 ± 0.11	119.6%
	60 s	5	1.72 ± 0.12	120.3%
5-0 Polydioxanone				
Group 1		6	1.51 ± 0.12	100.0%
Group 2		5	1.72 ± 0.13	113.9%
Group 3:	10 s	5	1.20 ± 0.35	79.5%
	30 s	6	0.66 ± 0.20**	43.7%**
	60 s	5	0.88 ± 0.12*	58.3%*
6-0 Polyglactin (undyed)				
Group 1		5	0.95 ± 0.03	100.0%
Group 2		5	1.03 ± 0.15	108.8%
Group 3:	10 s	5	1.12 ± 0.03	117.6%
	30 s	5	1.06 ± 0.10	112.2%
	60 s	5	1.12 ± 0.03	108.8%
6-0 Polyglactin (violet-dyed)				
Group 1		5	1.04 ± 0.04	100.0%
Group 2		6	0.99 ± 0.04	95.2%
Group 3:	10 s	6	1.09 ± 0.04	104.8%
	30 s	5	0.99 ± 0.12	95.2%
	60 s	5	0.69 ± 0.18	66.3%
7-0 Polydioxanone (violet)				
Group 1		6	0.56 ± 0.03	100.0%
Group 2		5	0.59 ± 0.02	105.4%
Group 3:	10 s	5	0.63 ± 0.05	112.5%
	30 s	5	0.30 ± 0.09*	53.6%*
	60 s	6	0.28 ± 0.05**	50.0%**
7-0 Polyglyconate (green)				
Group 1		12	0.74 ± 0.08	100.0%
Group 2		8	0.72 ± 0.08	98.2%
Group 3:	10 s	6	0.72 ± 0.05	97.0%
	30 s	8	0.77 ± 0.09	103.9%
	60 s	8	0.40 ± 0.20**	54.5%**

[a]Group 1 = no exposure to laser or glue; Group 2 = exposed to laser only; Group 3 = exposed to both laser and glue. [b]Number. [c]Kilogram force. * = $P < 0.05$ compared with group 1; ** = $P < 0.01$ compared with group 1.

tion are to the integrity of the underlying suture material. We studied the effects of laser glue on various suture types used in urologic surgery to identify ideal suture characteristics apropos to laser welding.

Laser activation of suture material may decrease its inherent tensile strength, particularly when chromophore is added to the solder. Ashton et al.[6] systematically studied 3-0 and 6-0 sutures commonly used in general and vascular surgery. The only suture material demonstrating a major drop in tensile strength (75% reduction) with diode laser activation (power density 9.6 W/cm^2) in the absence of solder was black-dyed silk. Of the 6-0 suture materials studied by Ashton [6], polypropylene (synthetic monofilament) showed the lowest tolerance for laser energy at the shortest exposure interval, whereas polytetraflouroethylene demonstrated the greatest tolerance. The authors attribute these differences to the higher melting point of polytetraflouroethylene (327°C) compared to polypropylene (130–170°C).

The diode laser energy wavelength is poorly absorbed by water and the sutures studied. The suture size, color, and presence of ICG dye in the solder contribute to the laser effect on the tensile strength of the suture. No apparent decrease in tensile strength was seen when undyed suture material was exposed to laser energy for up to 1 minute. However, the same was not true with smaller caliber, dyed microsutures (6-0 and 7-0). In these cases, the suture material was adversely affected by the presence of dye, resulting in a significant reduction in tensile strength compared to groups 1 and 2.

From these data, it appears that with the exception of 5-0 and 6-0 dyed polyglactin material, the presence of violet or green dye in the sutures contributes to the loss of tensile strength seen at 60 seconds laser exposure time. Our data on polyglactin material suggest that suture size may have an inverse effect on tensile strength retention during laser exposure. When comparisons are made between the various sizes of dyed polyglactin material, the largest caliber suture (4-0) was weakened, whereas the smaller caliber sutures (5-0 and 6-0) were not. These findings are consistent with those reported by Ashton et al.[6]. One exclamation for this finding is that larger structures (sutures) cool more slowly than smaller ones based on their increased volume/area ratio. As mentioned earlier, however, the significance of the original suture dye in laser energy

absorption is substantial, resulting in a greater decrease in suture strength compared to undyed materials of the same caliber.

Our technique of laser welding rarely involves sutures or tissues to be exposed for >5–10 seconds. Additionally, as the glue becomes dessicated and a green to tan color change occurs during the process, little glue may be available to absorb laser energy (Treat, pers. comm.). In the case of dyed sutures, particularly microsutures, the thermal effects of the laser render underlying dyed sutures vulnerable and will likely reduce their tensile strength. For these reasons, a thermally resistant suture material (undyed) may prevent disruption of wounds closed by primary laser welding or laser-assisted techniques.

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